Marine Biodiversity in the Mediterranean: Spatio-Temporal Variations, Interactions with Human Activities and Initiatives for Conservation

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1. Biodiversity: Definition, Values and Pressures

Although life includes different levels of organization (molecule, cell, individual, population, species, biocommunity, ecosystem) there are three categories included in the term '*Biodiversity*' or '*Biological Diversity*': i) *Genetic Diversity* (within species diversity), ii) *Species Diversity* (species number), iii) *Ecological Diversity* (community diversity)(Warwick, 1996).

Due to the close relationship between the scale approach and the natural processes studies regarding Biodiversity are in three different levels: *α-Biodiversity* [study of Biodiversity on a local scale in a particular habitat (*within habitat Biodiversity*) where all species compete for the same resources]; *β-Biodiversity* [study of Biodiversity in different habitats (*between habitat* diversity) in which interactions among different communities are observed]; *γ-Biodiversity* [study of Biodiversity on a large scale (*regional scale*) where the evolution processes rather than the ecological ones play a key role in determining of the diversity patterns (*landscape diversity*)(Ormund et al., 1997).

It is well recognized that Diversity of both Species and Habitats have many values for the human being (Costanza et al., 1992) such as: α) *Ethical Value* or '*the right to protect nature*' – the man has no right to exterminate his natural companions in the planet Earth no matter if these are or not valuable for the man himself, b) *Aesthetic Value* - Who has the right to leave the humanity without a unique construction of organisms such as the Great Barrier Reef in Australia; the culture in all civilizations from prehistoric time is closely related to the ecosystems and the different species they host, c) *Direct Economic Value* – Biological Resources apart their value for food are also unique for the substances they can provide which are valuable for the development of many different products in the Pharmaceutical and Cosmetics Industry. In recent studies performed by a group of Ecologists and Economists it has estimated that only in the USA the direct economic value of the environment is 33 tribilion $/year almost twice the GTP of that country (Pimentel et al., 1997; Daily et al., 1997). Even with this rather rough estimation it is obvious that the ecosystems and their resources provide different services in the human being (Fig. 1). It is therefore safe to conclude that whatever approach (i.e. economic, ecological, social, moral, etc.) will be taken into consideration, it is essential for sustainability reasons to conserve by all means the Biological Diversity (Costello, 2000).

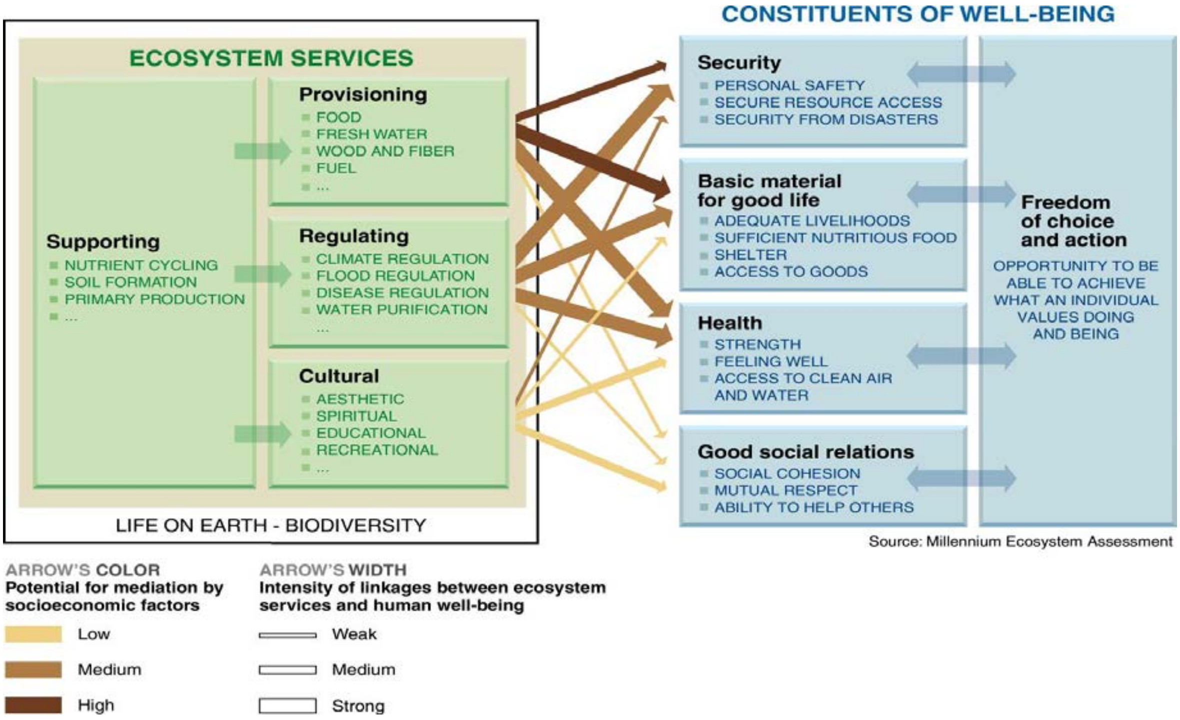

Fig. 1. A diagrammatic scheme showing ecosystem services essential for the well-being of the human communities.

1.1 Marine Environment and Biodiversity

The marine environment constitutes an important part of the global ecosystems. Indeed oceans and smaller seas cover the 71% of the planet Earth. The greatest depth reaches the 11.000m below the sea surface while the mean depth of the seas is 3800m. The total volume of the marine environment (1370x106km^3) offers almost 300 times more space for life in comparison with the correspondent one available in both the terrestrial and inland aquatic ecosystems. Considering the aforementioned one could claim that the name '*Earth*' for our planet is probably not realistic since earth is only a small fraction of the planet when compared with the marine realm (Pinet, 2000).

Every part in the seas from the shallow coastal bays to the deepest depth in the oceans is a special habitat hosting a smaller or greater variety of different forms of life. However, if we look at the '*Red Species List*' (the catalogue with the endangered species worldwide) we are going to discover that the number of species included there is continuously growing up. Another negative phenomenon is the increase of those marine species with a commercial fishery interest whose stocks are dramatically decreased at a critical point due to overfishing and destruction of their habitats (especially in the nursery grounds). In certain cases a whole collapse in the food chain and web has been recorded, while a severe change of the natural coastline is often met in various places around the world from the Caribbean to the Mediterranean Seas. The aforementioned phenomena are enough to give a clear picture of the serious problems the marine environment faces especially over the last decades (Castro & Huber, 1992).

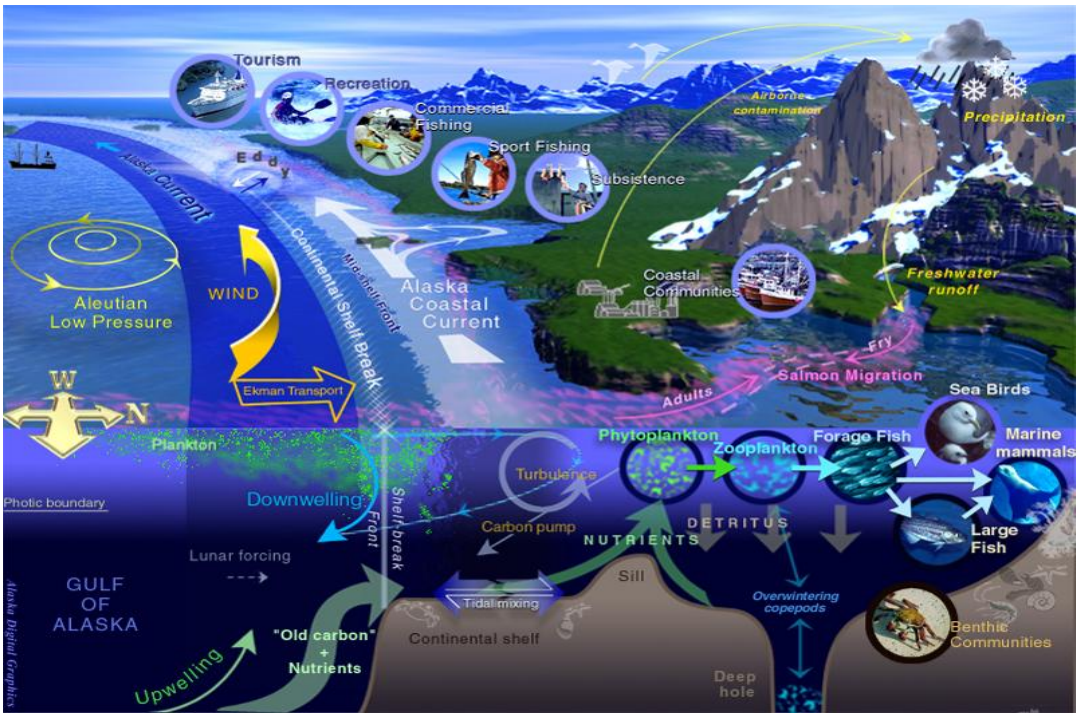

Fig. 2. A diagrammatic scheme showing natural ecosystem mechanisms in the marine environment and various anthropogenic activities in the coastal zone.

The rapid development of the anthropogenic activities especially after the 50's, along with the increase of the human population, have a severe effect in the marine ecosystems (Fig. 2): a) Pollution and Eutrofication; b) Changes in the morphodynamics of the coastal front; c) Overfishing; d) Invasion of allochthonus (alien or exotic) species; e) Global climate change in which are included the increase of the UV radiation and the increase of the sea temperature which subsequently change the sea currents and the dispersion of the nutrients which are a key element for the oxygen production and the primary production in the oceans. The impact on the marine biodiversity from these changes has already cause instability in the natural marine environment and this is documented in a series of cases: i) Dramatic decrease in the stocks of commercial invertebrates (e.g. molluscs, crustaceans) and fishes has been recorded worldwide (from 89 million metric tons in 1989 down to less than 70 in 1999) (Fig. 3), ii) Decrease of the population size or extinction of species containing valuable substances for drug, cosmetics or other biochemical products, iii) Loss of the aesthetic value in many coastal habitats (e.g. coral reefs, rocky shores, lagoons and estuaries, sandy beaches), iv) Dramatic changes in the composition and abundance of many flora and fauna species with a high ecological values for the natural function of the ecosystems, v) Changes in the mechanisms of the ecosystem such as the sources and rates of primary and secondary production, the flow of energy and the biogeochemical cycles.

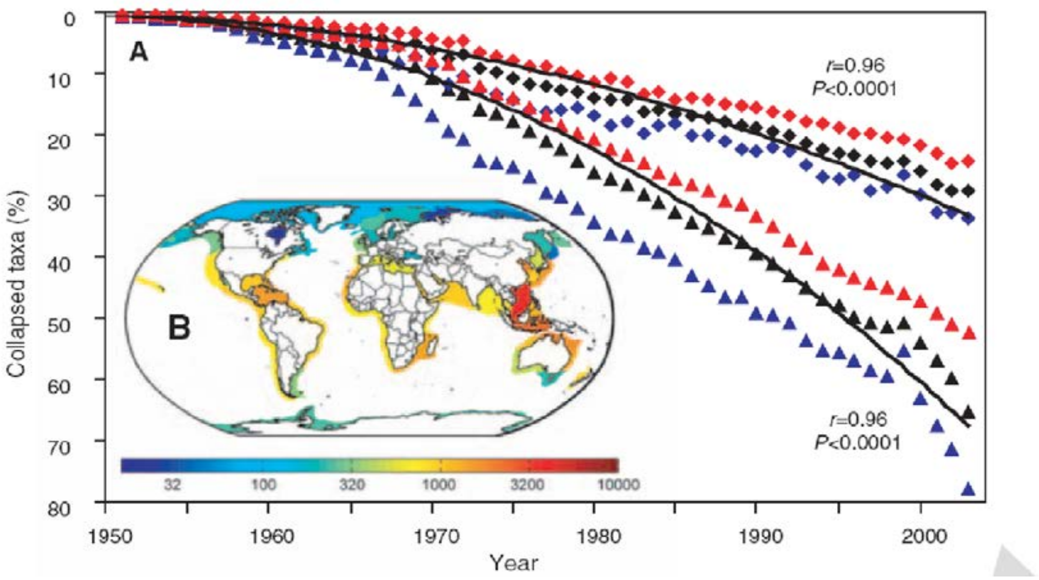

Fig. 3. A diagrammatic scheme showing the dramatic loss of commercial stocks in the forthcoming years in the case fisheries will be going on with the now days exploitation rhythms (after Worms et al. 2006 – SCIENCE).

1.2 International Policies and Legislation for Biodiversity Conservation under Sustainability and Rational Development

It is evident that if conservation of biodiversity under a sustainable or rational development approach is a priority for the human being, certain actions are necessary to be undertaken for an effective protection of the marine ecosystems (Catizzone, 1999; Raffaelli et al., 2004).

Indeed in the UNCD Assembly organized in Rio (1992) a Convention for the Biodiversity was established (*Convention on the Biological Diversity*, *CBD*), which few years later (2000) was reinforced in the new Assembly in Jakarta. In the CBD particular actions aiming towards the effective conservation of biodiversity worldwide are included and these actions should be activated by the different nations which have signed this Convention. These actions, which have been adopted by the European Communities and constitute the EU Policy – Fig. 4) are summarized below:

- Development of National Strategies for the conservation and sustainable use of biodiversity
- Consideration of biodiversity in Environmental Impact Assessment Studies in the Spatial Planning and Development in every region
- Monitoring, conservation and rehabilitation of biodiversity through the establishment of ‘*Protected Areas*’ and ‘*No-take Zones*’
- No use of products from genetic muted organisms

- Development of Environmental Education and Public Awareness regarding the biodiversity

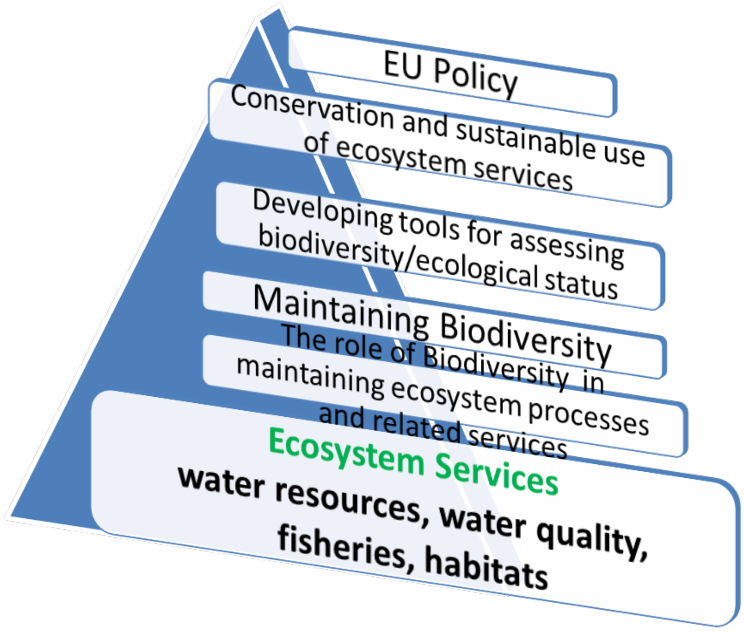

Fig. 4. A diagrammatic scheme showing the EU Policy for particular actions regarding the Conservation of Biodiversity according to the *'Convention on the Biological Diversity, CBD'*.

2. Marine Biodiversity in the Mediterranean

As explicitly has been documented above it is widely recognized not only by the Scientists, but also the Mass Media, the Stakeholders and the Public Opinion that biodiversity assessment is the appropriate index for the evaluation of the health of the environment and the good status of the ecosystems. However, and despite the fact that the biggest part of the planet Earth is covered by oceans (Blue Planet), it is the terrestrial environment and not the marine one which has attracted the concern of the public opinion and the government worldwide. The Mediterranean is not an exception in this rule despite its great environmental, cultural and economic value.

The present status of the marine biodiversity in the Mediterranean and the negative effects due to the anthropogenic activities and the global climate change, along with the EU policies under a sustainable and rational development approach are presented below as an example of environmental issues with global interest.

2.1 Physiognomy and Features of the Mediterranean

The Mediterranean Sea, in its present form, is a unique sea worldwide. Despite its surface is 2.500.000km^2 and the length of its coasts reaches 46000km (bigger than the Earth perimeter in the equatorial), the Mediterranean constitutes a very small sea when compared with the global oceans (0.7% of the Ocean's surface, 1/35 of the surface of the neighboring Atlantic Ocean). For its small size this basin has a rather extended Continental Shelf since this covers 17% of its total surface *vs* 7.6% of the Continental Shelf surface in the Global Oceans. Its mean depth is small (1429m) *vs* the mean depth (3800m) in the Oceans, while abyssal depths (depths from 3000 to 6000m), which cover almost ¾ of the Oceans, in the Mediterranean is less than 10% (Mojetta, 1996).

The Mediterranean has an extended sunshine (18-22kcal solar radiation/cm^2 surface), which in relation to the fact that this sea is rather an isolated basin, has as a result the sea temperature to be rather warm and this contributes of a rather calm climate, well known as the '*Mediterranean Climate*'. The solar radiation and the prevailing winds (warm and wet during the summer – dry and from the land towards the sea during the winter) have as a result the Mediterranean to present high evaporation rhythms (3000km^3 of water are evaporated) in comparison with other seas of similar size. This subsequently has an effect on the physico-chemical and biological features of this basin.

The particular characteristic climatic features of the Mediterranean have resulted in the appearance of a thermocline (warmer surface waters – colder deeper waters) especially during the summer period. In the winter due the water mixing this thermocline is destroyed thus resulting in the movement of the surface waters in the deeper depths caring enough quantities of oxygen (essential for the living forms there) and the same time in the movement of the rich in nutrients (essential element for the photosynthetic plankton and benthic primary producers) deeper waters towards the surface (photic zone), while the sea temperature in the whole pelagic zone never falls below 10^{0}C throughout the year.

The Mediterranean is a relatively isolated basin since it communicates with other seas and oceans through three narrow channels: a) the *Gibraltar Straits* - 17km wide, maximum depth 350m – through which it communicates with the Atlantic Ocean, b) the *Suez Canal* - 400m wide, maximum depth 80m - through which it communicates with the Red Sea and the Indo-Pacific Ocean, c) the *Bosporus Channel* through which it communicates with the Black Sea (a sea which is considered by certain authors as an '*internal basin*' of the Mediterranean).

Due to the fact that evaporation is higher than the input of fresh water and the rainfall in the Mediterranean there is a water loss in this basin. Therefore, the Gibraltar Straits is considered as the 'umbilical stripe' of the Mediterranean considering the supply in water. The water loss in the Mediterranean is quite important and if for some reason there was a closure of the Gibraltar Straits this basin would become an almost '*dry land*' within a time period of 1000-1500 years (something which indeed has occurred in the Mediterranean almost 3 million years ago during the Messinian Crisis). Therefore, cold and low salinity (35-36psu) water from the Atlantic Ocean enters the Mediterranean through the Gibraltar Straits as a surface current. However, warm and high salinity (38-39psu) water is coming out from the Mediterranean towards the Atlantic again through the Gibraltar Straits as sub-surface current (Fig. 5).

According to its geomorphological, climatic and biological features the Mediterranean basin is divided to 2 sub-basins (Fig. 6): the Western and the Eastern

Mediterranean with the Sicily-Tunissien border (400m depth) as a natural border of these two basins (Frantzis, 1999).

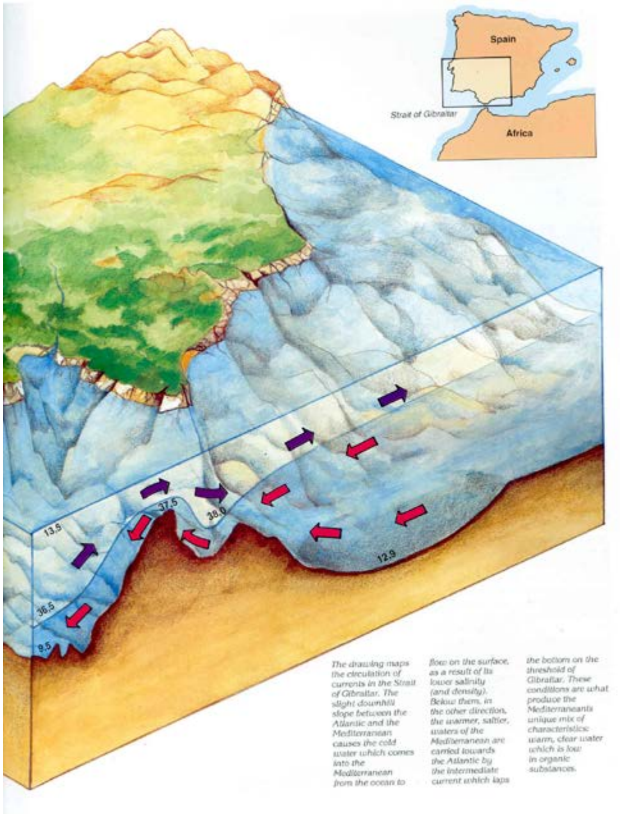

Fig. 5. Water exchange between the Mediterranean Sea and the Atlantic Ocean, through the Gibraltar Straits (after Mojetta, 1996).

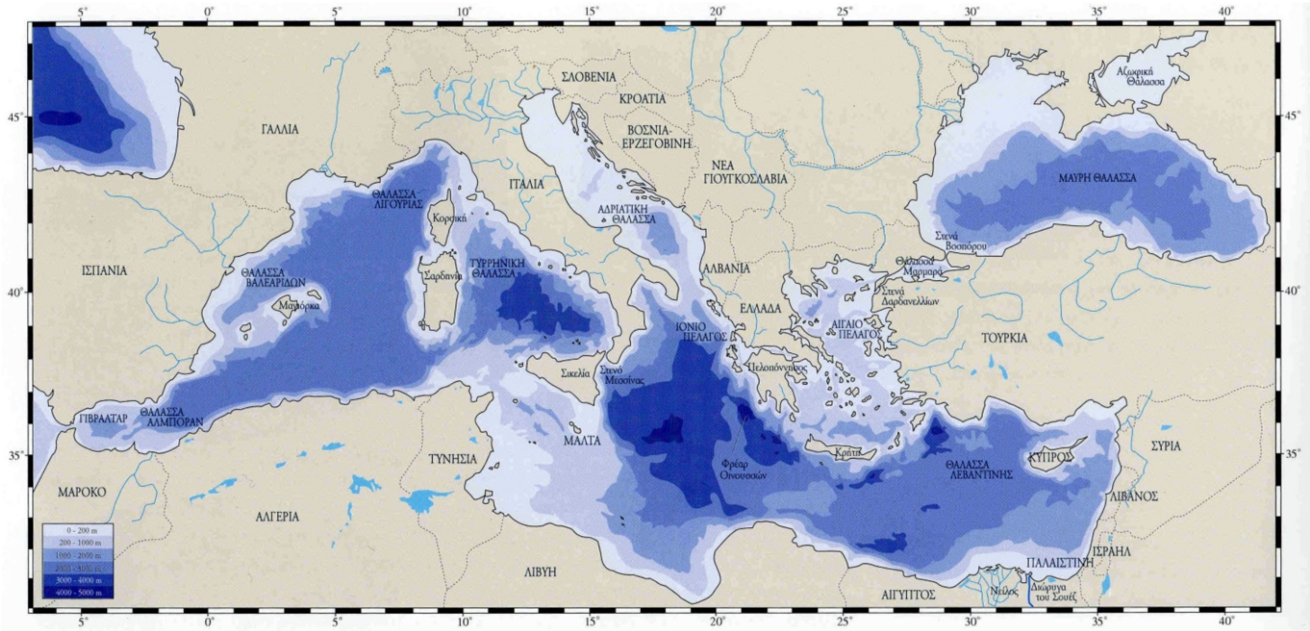

Fig. 6. The Mediterranean Sea with its bathymetry. The Sicily-Tunissien border (400m depth) is the ‘natural frontier’ dividing this sea into 2 water basins, ie. The Western and the Eastern Mediterranean (after Frantzis, 1999).

2.2 Diversity of Marine Organisms in the Mediterranean Sea

The Mediterranean Sea is a basin with a high diversity if marine organisms. According to recent efforts of the scientific community (e.g. Mojetta, 1996; Bianchi & Morri, 2000; EEA, 2003) who have taken into consideration all available electronic databases, species checklists, etc. (which were lacking in the past) the number of species living in the Mediterranean is estimated to overpass 8.500 species considering the macroscopic flora and fauna (Table 1). This corresponds to 8.5% of the number of species distributed in the global Oceans (from 5% to 17% of the number of species globally depending on the taxonomic group considered). The number of species living in the Mediterranean is expected to further increase in the near future when research efforts will efficiently cover either habitat types (e.g. deep seas, underwater caves) or geographical locations (e.g. coasts of north Africa, coasts of Lebanon and Syria in the Levantine Basin) which have scarcely been studied so far. However, even with the already existed knowledge, the number of species in the Mediterranean is high especially when taking into consideration that this basin is only 0.82% of the surface and 0.32% of the volume of the global oceans (Bianchi & Morri, 2000).

Table 1. Number of macroscopic species in the Mediterranean in comparison with the global Oceans (after Bianchi & Morri, 2000).

Taxonomic Groups	Global Oceans	Mediterranean Sea	Mediterranean/ Global Oceans (%)
Rhodophycae (Red Algae)	5250	867	16.5
Phaephycae (Brown Algae)	1500	265	17.7
Chlorophycae (Green Algae)	1200	214	17.8
Marine Angiosperms	50	5	10.0
TOTAL PLANTAE	8000	1351	16.9
Porrifera (Sponges)	5500	600	10.9
Coelenterata (Cnidozoans)	11000	450	4.1
Bryozoa	5000	500	10.00
Worms (Polychaeta & Oligochaeta)	8000	777	9.7
Mollusca	32000	1376	4.3
Arthropoda (Crustacea)	33600	1935	5.8
Echinoderma	6500	165	2.2
Chitonophora	1350	244	18.1
Other Invertebrate Groups	~13500	~550	4.1
TOTAL INVERTEBRATA	~116500	6575	5.6
Chondrichthyes	850	81	9.5
Osteichthyes	11500	532	4.1
Reptilia	58	5	8.6
Mammals	118	21	18.4
TOTAL VERTEBRATA	12522	639	5.1
GRAND TOTAL	~137000	~8565	6.3

…. Why the Mediterranean Sea has a high diversity? …. One of the reasons for this is the fact that this basin is one of the best studied seas of the world considering the marine environment and its biota. The first information for the marine organisms of the Mediterranean Sea has already been given 2000 years ago by Aristotle (the first and in many ways the greatest of all naturalists, made in ancient

times for his excellent info he has presented in his *STORIA ANIMALIA* could also be considered as one of the pioneers in the Marine Biodiversity studies). Furthermore, already after the Renaissance (15th – 16th Centuries), numerous scientists – mainly from France, Spain and Italy – have devoted a lot of effort in studying the marine ecosystems of the Mediterranean. The high diversity of the Mediterranean Sea is also the result of the diverse environmental, geomorphological and hydrological changes which have occurred over its long geological evolution history. These changes, along with the current climatic and hydrodynamic dynamics occurring in the Mediterranean Sea, have resulted the present marine biota of this basin to be composed of species belonging to several Biogeographic categories (Bianchi & Morri, 2000; Koutsoubas, 2004 and References therein): (i) a temperate *'Atlantic-Mediterranean'* background (distributed in the NA Atlantic Ocean from the Moroccan coasts in the south to the Iberian Peninsula in the north and also in the Mediterranean). These species constitute 40-45% (depending on the taxonomic group) of the total number of species distributed in the Mediterranean; (ii) *'Cosmopolitan/Panoceanic'* species. These constitute 4-6% (depending on the taxonomic group) of the total number of species distributed in the Mediterranean, and their entrance in the basin has been mainly achieved through the Gibraltar Straits; (iii) *'Endemic'* elements, comprising both 'Paleo-endemic' species (possibly of Tethyan origin – less than 0.2% of the total Mediterranean species) and 'Neo-endemic' species (mainly of Pliocenic origin – almost 25% of the total number of the Mediterranean species). For the presence of the 'Paleo-endemic' species in the recent Mediterranean two interpretations have been given: (a) these species have survived in small water bodies of the Mediterranean during the 'Messinian Crisis' (a period during which the Mediterranean was almost drained out of water due to the closure of the Gibraltar Straits– almost 6.5 million years ago), (b) these species have moved outside the Mediterranean in the Atlantic or the Pacific Ocean during the 'Messinian Crisis' and came back in the basin after this crisis, either through the Gibraltar Straits or the Suez Canal. The *'Endemic'* species constitute almost ¼ of the total number of species distributed in the Mediterranean. This high percentage of endemism is a unique characteristic of this basin; (iv) *'Subtropical Atlantic'* species (interglacial remnants, especially of the Tyrrhenian Stage). These 'warm water' or 'thermophilic' species which constitute 1.5-3% (depending on the taxonomic group) of the total number of species distributed in the Mediterranean, and are usually distributed in the surface and coastal waters of the south and eastern parts of the basin; (v) *'Boreal Atlantic'* species (ice-ages remnants, especially of the Würm glacial). These 'cold water' species which constitute 10-15% (depending on the taxonomic group) of the total number of species distributed in the Mediterranean, are inhabitants of the deeper parts of the basin; (vi) *'Red Sea and Indo-Pacific Ocean migrants'* (especially into the Levant Sea) through the Suez Canal (after its opening in 1869). These are also 'thermophilic' species and constitute 6-8% (depending on the taxonomic group) of the total number of species distributed in the Mediterranean; (vii) *'Western Atlantic migrants'* (especially into the Alboran Sea). These constitute less than 0.5% of the total number of species distributed in the Mediterranean.

In comparison with the neighboring Atlantic Ocean the marine communities of the Mediterranean Sea are characterized by higher diversity, while the species composing these communities are characterized by smaller size (a phenomenon termed '*Mediterranean Nanism*') and life-cycle (Bellan-Santini et al., 1994).

A considerable number of marine organisms of the Mediterranean are distributed in the Greek Seas (almost 3000 macrobenthic species have been recorded so far from these seas – 50% of the total number of species known from the Mediterranean Sea)(Table 2).

Table 2. Number of macrobenthic fauna species in the Greek Seas in comparison with the Mediterranean (after Chintiroglou et al. 2005).

MACROFAUNAL GROUPS	MEDITERRANEAN SEA	GREEK SEAS		
	Mojetta, 1996; Bianchi & Morri, 2000	Stergiou et al., 1997	Koukouras et al., 2001	Chintiroglou et al., 2005
Porrifera (Sponges)	600	117	170	189
Anthozoans (Cnidozoans)	153	23	76	88
Polychaeta	1037	570	561	593
Sipuncula	28		9	9
Aplacophora	6			2
Solenogastres	30			1
Polyplacophora	30		19	19
Gastropoda	1320	637	622	670
Bivalvia	405	300		305
Scaphopoda	16			12
Cephalopoda	59			29
Cirripedia	34	18		18
Amphipoda	449		260	260
Isopoda	165		74	74
Tanaidacea	43		18	18
Cumacea	91		52	52
Decapoda	374	231	252	252
Bryozoa	420	200		192
Echinoderma	162	107	108	108
Ascidians	187		67	67
Small invertebrate groups		100		
GRAND TOTAL	**5598**	**2655**	**2306**	**2960**

The smaller number of species of the marine biota and in particular the macrofaunal benthic organisms reported above and are known to live in the Greek Seas is a reflection of the marine diversity pattern (regarding all taxonomic groups – algae, fishes, etc. in the Plantae and Animalia Kingdoms) of the Mediterranean Sea. According to this diversity pattern the different regions of the Mediterranean biodiversity is declining from the Western towards the Eastern basin (Fig. 7). Three zones can be distinguished in the Biodiversity pattern of the Mediterranean: (a) '*High Diversity Zone*' in which only the Western Mediterranean is included, (b) '*Moderate Diversity Zone*' in which the Central Mediterranean, the Adriatic Sea, the Aegean Sea and the Levantine Basin are included, (c) '*Low Diversity Zone*' in which the Marmara Sea, and the neighboring of the Mediterranean Black Sea are included.

The main reasons for the lower biodiversity in the Eastern Mediterranean should be attributed to different reasons: a) in the density and spatial coverage of research activities which are by far much more in the western part of the basin, b) in the oligotrophic character of the eastern part of the Mediterranean (low nutrients concentrations, low primary production), c) in the greater distance of the eastern part of the Mediterranean from the Gibraltar Straits through which the greater percentage of species from the Atlantic Ocean enter in the Mediterranean (the larval life of the majority of the species – not exceeding the 7-9 weeks - is a limited factor for the dispersal of these species in the eastern basin), d) in the higher temperature and salinity values occurring in the eastern part (especially in the Levantine Basin) of the Mediterranean, which make unfavorable this region for many of the marine organisms distributed in the Mediterranean (many of the species in that sea originate from the cold and less saline water of the Atlantic Ocean).

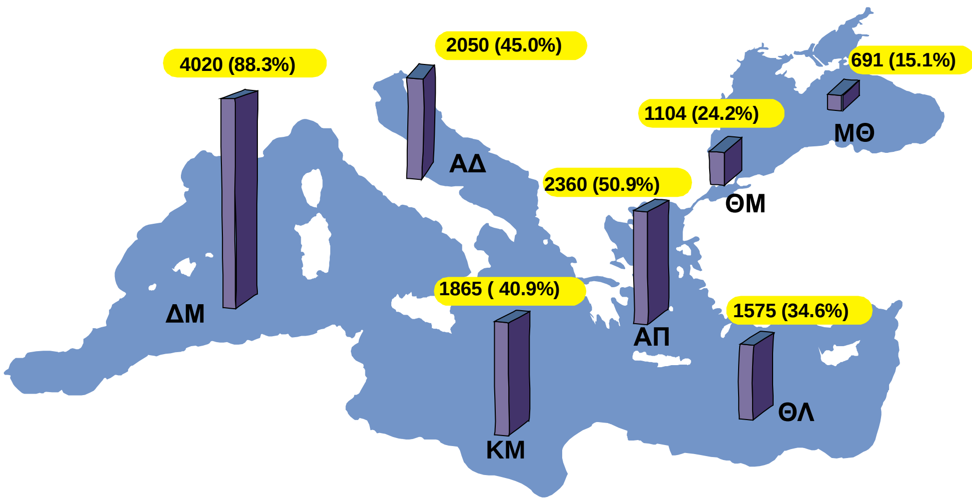

Fig. 7. Distribution of macrobenthic fauna species in the different regions of the Mediterranean Sea and the Black Sea, both in absolute numbers and in percentages of the total number of species living in the Mediterranean (ΔΜ = W. Mediterranean, ΑΔ = Adriatic Sea, ΚΜ = Central Mediterranean, ΑΠ = Aegean Sea, ΘΛ = Levantine Basin, ΘΜ = Sea of Marmara, ΜΘ = Black Sea)(after Koutsoubas, 2005).

3. Anthropogenic Activities and Impacts on the Biodiversity of the Mediterranean

The Mediterranean Sea is located in one of the most densely populated areas worldwide, since in the coasts surrounding this basin live more than 450 million people. The pressure of the human being in that sea is becoming more severe, if somebody would take into consideration that an additional number of tourists from all over the world visit for a period of time (especially during summer) the resorts widespread around the Mediterranean. The 'Mediterranean Climate' along with the natural and cultural characteristics of this Sea attract almost 1/3 of the worldwide tourism and this number is estimated that will be increased in the future (the number of tourists is estimated to increase from 135 million in the 90's in more than 300 million in 2025 - UNEP-RAC, 1995).

There is no doubt that the anthropogenic activities of the permanent or temporal population of the Mediterranean do have an impact on the natural ecosystems and the biodiversity of this sea (EEA, 2003). The different forms of anthropogenic stress and the impacts on the ecosystems are briefly presented below:

a) Eutrophication, as a result of agricultural cultivation, population increase or tourism. Eutrophic conditions resulting in phytoplankton blooms is a phenomenon which is regularly reported in certain areas of the Mediterranean such as the Adriatic, the Lion Gulf in the French coasts and the N. Aegean (Thermaikos Gulf). In certain cases – still to a reduced spatio-temporal scale – Harmful Algal Blooms, which are known to severely affect public health (through the consumption of marine biological resources such as shellfish and fish) have been reported.

b) Microbial Pollution, which in most of the cases is related to domestic sewage effluents in the marine environment and potentially may have a severe effect in the public health (again through the consumption of infected seashells and particularly bivalves). In addition the effluent of pathogenic microorganisms in the marine environment may cause diseases and death in certain species of the biota (the increased number of dead dolphins in some areas of the Mediterranean has been attributed to the microbial pollution by human activities). This kind of pollution could be solved to a certain degree by the development of Biological Treatment Stations (BTS) in the major cities in the Mediterranean Coasts. The high standards set by the tourist domain regarding the quality of the bathing sea water (Blue Flag Coasts) has led the last decades the European Union as well as other non EU members around the Mediterranean to adopt a Legislation towards implementation of BTS in all coastal cities with a population over 20.000 inhabitants. However, still over than 80% of the domestic effluents of the coastal areas reach the open sea without any prior treatment in BTS.

c) Industrial and Hydrocarbon Pollutants. In certain areas of the Mediterranean Sea (mainly in France and Italy but also in Spain in the Western Mediterranean and to a lesser degree in Serbia, Montenegro and Turkey in the Eastern Mediterranean Sea), there is a high industrial activity resulting in the effluent of industrial wastes (e.g. heavy metals – Zn, Cr; iron wastes) in this Sea. Furthermore, in many areas of the SE Mediterranean countries (Algeria, Libya, Egypt, Syria, etc) major oil platforms and oil installations exist thus resulting in hydrocarbons pollution events. Major problems of this kind of pollution are more evident in the NW Mediterranean where huge Industries and also major Harbors with high navigation exist. In these areas pollution events with toxic bio-accumulated pollutants such as TBT have also been reported over the last two decades.

d) Invasion of allochthonus or exotic species. The Mediterranean Sea the last century and especially over the last two decades is suffering the invasion of more than 700 allochthonus, exotic or non-indigenous species (species which are originated from other sea basins of the world)(EEA, 2003; Galil, 2009; Raitsos et al. 2010). These organisms belong to different major flora (algae, phanerogams) and fauna (invertebrates and fishes) taxonomic groups. The major modes of invasion of these allochthonus species in the Mediterranean are the natural migration through the Suez Canal (Lessepsian migration), the navigation (transport of species via the ballast water of the many ships arriving from different areas of the global oceans), the deliberate import or the accidental escape of many species used either as a fish bait, or for exhibition in aquaria. The invasion of these species in the Mediterranean has already resulted in the change of the biogeographic profile of this sea, especially of those areas located in the Eastern Basin neighboring the Suez Canal such as the Levantine Sea in which already a 30% of the species living here are allochthonus species. The high rate of invasion, especially over the last decade, is closely related to global climate change which is evident also in the Mediterranean (an average of almost 2.5^{o}C increase of the sea temperature has been recorded over the last 20 years in the Mediterranean – EEA, 2005, thus favoring the warm tropical species to successfully establish in this basin – Galil, 2009). The increased rhythm of invasion in the Mediterranenan has caused a series of both economic and ecosystem changes. Regarding the economic importance many of the species which have entered the Mediterranean have a high economic value since these are commercial species (e.g. pearl oysters, Indo-Pacific clams, Prawns). The ecological changes – even if these cannot be still evaluated with accuracy – are also significant since many of the invasive species result in a dramatic loss of the autochthonus or indigenous species populations or even in the extinction of these species, which subsequently lead to ecological unbalance (habitats loss, collapse of trophic webs, etc). An example is the invasive green algae *Caulerpa toxifolia* which has escaped from the Monaco Aquarium in the Mediterranean French Coasts and then expanding its distribution to other areas of the Western and Central Mediterranean Sea occupying habitats of autochthonus species (e.g. the Neptune's seagrass *Posidonia oceanica*) and causing severe ecological disturbance. In this particular example the *Posidonia* loss has a severe impact also to the natural populations of many flora and fauna species composing the biocommunities of these seagrass meadows.

e) Overfishing of Biological Resources. The fishing activities in the Mediterranean Sea has an increase of more than 12% in the last decade and has led to an over exploitation of resources in many demersal and pelagic (mainly tuna and swordfish) species (Worm et al. 2006; http://www.ocean2012.eu). Overfishing – many times by means of illegal fish tools – has led to a dramatic decrease the populations of many benthic invertebrates with a commercial interest (e.g. the red coral *Corallium rubrum*, the bivalve species *Lithophaga lithophaga*). Such an activity also has dramatic effects to populations of other invertebrates presenting a minor commercial value such as the bivalve *Pinna nobilis* (the common fan shell, the biggest bivalve in the Mediterranean).

f) Aquaculture. Aquaculture activities (mainly of bivalve and fish species) has been increased more than 50% over the last 20 years in the Mediterranean (from 40.000tns in 1984 to more than 120.000tns nowadays). Despite the increased aquaculture activities in various areas of the Mediterranean, in the majority of cases, negative impacts concerning biodiversity of the communities living in the natural ecosystems neighboring the fish cages have not been recorded, opposite to what has been reported in many other Seas of the world and especially the European Countries (e.g. the Baltic and North Sea) in which similar activities exist. The lack of negative impacts on the Mediterranean coastal areas with aquaculture activities should probably be attributed to the oligotrophic character of the Mediterranean Sea (Karakassis et al., 1999).

4. Biodiversity Conservation – Marine Protected Areas in the Mediterranean

The first legal framework referring to Marine Protected Areas as a basic approach and prerequisite for biodiversity conservation in the Mediterranean has been adopted by all Mediterranean Countries in Geneva back in 1982 (Geneva Convention). After the '*Convention on the Biological Diversity*, CBD' adopted in Rio (1992) it was obvious that there was a need to reconsider the Geneva Convention and this resulted in the setup of a new framework in 1995 in Barcelona (Barcelona Convention) and the development of a '*Protocol for the development of Special Protected Areas*' in the (Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean' or SPA Protocol) (Pavasonic, 1996). This new Protocol has led to the establishment of local/national as well as international (managed by 2 or more different countries) Marine Protected Areas (MPAs - Marine Protected Areas). An important output of the Barcelona Convention was the adoption of a List including all protected areas in that basin, also known as SPAMI List (Specially Protected Areas of Mediterranean Interest) (Fig. 8). The responsible Organization for the implementation of this Protocol by all Countries surrounding the Mediterranean and also the establishment of a Marine Protected Areas Network in this basin is the RAC/SPA (Regional Activity Centre for Specially Protected Areas). From the aforementioned is obvious that the track history of Protected Areas in Europe is rather recent. Indeed the 1st MPA was established in France back in the late 70s and then similar Protected Areas were developed in France and Greece (in the late 80s), and in Italy (beginning of 90s). Till 1999 a total of 35 MPAs had been developed in EU members bordering the Mediterranean Sea (5 in France, 11 in Spain, 16 in Italy, 2 in Greece and I in Cyprus). Nowadays a total of 65 MPAs (Goni et al., 2000) exist in the Mediterranean since many MPAs have also been developed in non EU members also surrounding the Mediterranean (Adriatic Sea – Croatia, Slovenia, Serbia; Levantine Basin – Israel, Lebanon, Turkey; North African Coasts – Algeria, Tunisia and Morocco).

The term 'Marine Protected Area' refers to '*.... designated marine sites in which a management activity supported by a particular legislation for a conservation status.....*'(UNEP-RAC/SPA, 1997). The conservation status covers not only the abiotic and biotic natural environment in a particular area but in addition the cultural and historical monuments and characteristics of this particular area. The main goal of an MPA established in a particular area is the protection of the natural resources, the protection of 'endangered species, or the protection of particular habitats which are representative of the Mediterranean and thus are considered as 'environmental culture of this basin'. It is evident that through this approach a MPA aims not only towards environmental protection, but additionally to the conservation of the cultural heritage of an area. Furthermore the establishment of an MPA aims to support the local economy through sustainable development and alternative resources of income such as the increase in eco-tourist activities (e.g. Diving and Sport Fishing Tourism, Bird Watching and other Wild Life Activities). Finally the important support in issues related to educational and research should alo be considered in an MPA.

Fig. 8. Marine Protected Areas in the Mediterranean Sea (from López Ornat, 2006).

In order to achieve the goals of conservation within an MPA a zoning scheme with different activities is usually required (Fig. 9). Therefore, there are: a) the Higher Protection Level Zone in which usually access is permitted only to scientific staff for research activities and, b) the one or two less Restrictions levels Zones in which certain anthropogenic activities (e.g. tourism) with no impacts on the natural environment are aloud. A basic prerequisite for an effective management and conservation in an MPA is the acknowledgment of these policies by the local Community. This may be achieved by a proper Environmental Marine Spatial Planning which should take into consideration a continuous effort for public awareness and proper distribution of info as well as an effort to perform particular actions and use appropriate means and tools towards sustainable development.

The criteria for the selection of an area as an MPA usually are based on the existence of ‘rare beloved’ species (e.g. Logger-head sea turtles *Caretta caretta*, Monk Seals *Monachus monachus*, Dolphins and other Mammals) or on the distribution of particular habitats and ecotopes such as ‘rocky habitats’ and ‘coralligenous formations in an area. The selection of a particular criterion when designing an MPA often acts as a stimulus for a higher number of visitors in the area, since alternative tourism is considered as a main resource of income for the local community. However, a careful design of these wild-life activities is necessary to be designated since the massive attraction of tourists may have severe impact on the natural environment and its biota (e.g. without monitoring and strict restrictions in the number and experience status of divers may cause great damages in the benthic communities and loss of 'sensitive and fragile' marine organism such as bryozoans and corals). A detailed effort in designation of particular 'underwater routes' and public awareness (e.g. environmental education, production of special leaflets) along with the adoption of certain precautionary measures is necessary if the conservation and rational management of resources in an area remains a primer target.

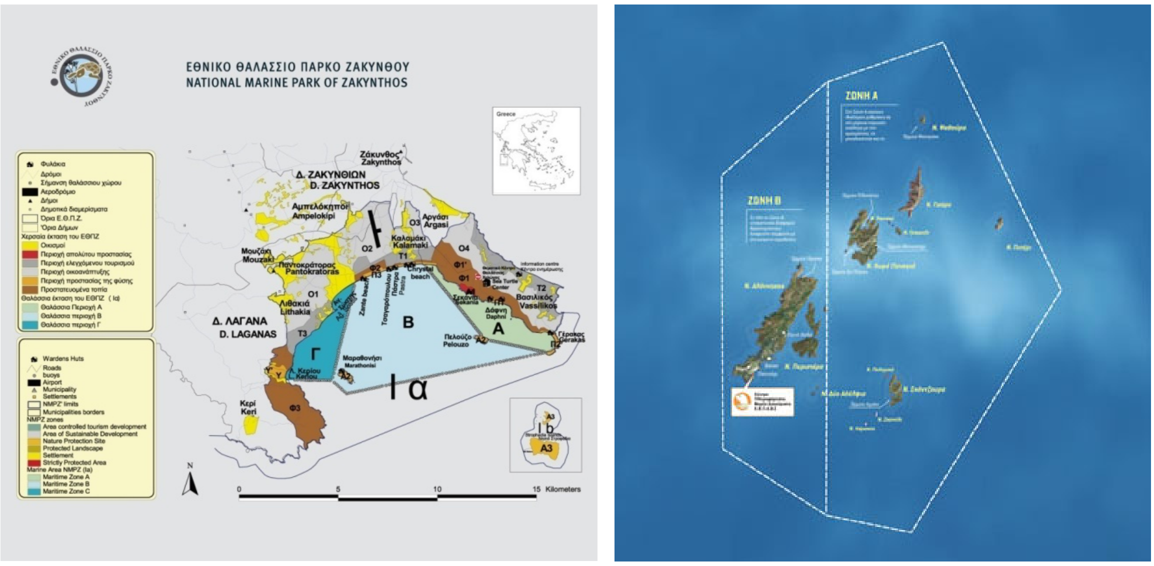

Fig. 9. The National Marine Park of Zakynthos (N.M.P.Z.) and the National Marine Park of North Sporades and Alonissos, the two MPAs in Greece with a Management Body, in which the zoning with different restriction measures is shown (e.g. Zones A and B in which the main nesting beaches of the loggerhead sea turtle *Caretta caretta* are located have a more restricted regime within the Park. More in particular, Zone A in the NMPZ is an area where only research activities are allowed, Zone B is an area where soft tourist activities and navigation of small boats with a speed less than 6 nautical miles/hr is allowed; also in all Zones fishing with particular commercial fishing tools – trawlers and longline boats - is prohibited year around and fisheries with nets and fyke nets is allowed only for six months – from November to end of April when the reproductive period and nesting of Sea Turtles occur in the Park).

In the Greek Seas exist two MPAs in which there are established Management Bodies and the appropriate personnel (Nature Guards or Park Rangers and Sccientists – Biologists, Oceanographers, Ichthyologists, Environmental Economists for Management, etc) guarantees the safe protection of the habitats and the endangered species. The effort of the Management Bodies of these two MPAs usually are significantly supported by particular Environmental Non-Governmental Organizations (e.g. 'ARCHELON' Sea Turtle Protection Society, 'MOM' Monk Seal Protection Society, 'HOS' Hellenic Ornithological Society).

The first MPA the National Marine Park of Zakynthos (Presedential Degrees 1999 and 2001), with a surface of 92 Km² is located in the Ionian Sea and aims to protect the conservation of the loggerhead Sea Turtle *Caretta caretta* and the Marine and Coastal Habitats of Community Interest in the Laganas bay and the Islands of Strofadia (areas of Zakynthos included in the Park). In the Laganas Bay nesting beaches a considerable number of sea turtles lay their eggs every year (almost 50% of the nesting sea turtles of the Greek Seas and 25% of the total Mediterranean population).

The second MPA the National Marine Park of Northern Sporades and Allonisos, with a surface of 265 Km², is located in the central part of the N. Aegean Sea and aims to protect one of the most endangered species of the Mediterranean biota, i.e. the Monk Seal *Monachus monachus* (almost 50% of the Mediterranean population is distributed in Allonisos and the small islets around this island).

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